

CLAIMS

WE CLAIM:

1. A turbine blade for a gas turbine engine, comprising:
an airfoil having at least an outer surface, a bottom edge, and a top edge;
a plurality of internal cooling channels formed in the airfoil; and
a plurality of film cooling holes extending through the airfoil and in fluid communication with one of the internal cooling channels, the plurality of film cooling holes arranged into at least two adjacent rows, each row disposed on at least a portion of a line that extends between the airfoil top and bottom edges, and each film cooling hole having a centerline extending therethrough,
wherein:
 - (i) the centerline of each film cooling hole forms a compound angle with respect to a tangent of the airfoil outer surface, and
 - (ii) a distance between the centerlines of each film cooling hole is at least a predetermined minimum distance.
2. The turbine blade of Claim 1, wherein each film cooling hole in each row is offset from each of the film cooling holes in the adjacent row.
3. The turbine blade of Claim 1, wherein the compound angle of each film cooling hole centerline comprises at least a first angle formed with respect to a first predetermined datum structure and a second angle formed with respect to a second predetermined datum structure.
4. The turbine blade of Claim 3, wherein:
each film cooling hole has an inlet port and an outlet port; and

the outlet port of each film cooling hole is located a first predetermined distance from the first datum structure and a second predetermined distance from the second datum structure.

5. The turbine blade of Claim 3, wherein the first and second predetermined datum structures are first and second datum planes, respectively.

6. The turbine blade of Claim 5, wherein the first and second datum planes are disposed perpendicular to one another.

7. The turbine blade of Claim 1, further comprising:
a mounting section coupled to the airfoil bottom edge and adapted to couple to a turbine wheel, the mounting section including one or more coolant flowpaths extending therethrough and in fluid communication with one or more of the internal coolant channels.

8. The turbine blade of Claim 1, wherein the centerline of each film cooling hole forms an angle with respect to a tangent to the airfoil outer surface that is between about 15-degrees and about 30-degrees.

9. The turbine blade of Claim 8, wherein the angle is less than about 20-degrees.

10. The turbine blade of Claim 1, wherein the predetermined minimum distance is between about two and about four times a hole diameter.

11. A method of forming a plurality of film cooling holes in a turbine airfoil having an outer surface and a plurality of internal cooling channels, the method comprising the steps of:

defining at least a first datum structure and a second datum structure;

forming each of the plurality of film cooling holes through the airfoil, and into fluid communication with one of the internal cooling channels, at a location on the airfoil outersurface relative to the first and second datum structures, each film cooling hole having a centerline extending therethrough that forms a compound angle with respect to a tangent of the airfoil outer surface.

12. The method of Claim 11, wherein the compound angle of each film cooling hole centerline comprises at least (i) a first angle formed with respect to the first datum structure and (ii) a second angle formed with respect to the second datum structure.

13. The method of Claim 11, wherein:

the first and second datum structures are first and second datum planes, respectively; and

each film cooling hole is located at a position relative to the first and second datum planes.

14. The method of Claim 13, wherein:

the position of each film cooling hole relative to the first datum plane is determined by:

rotating a first locator plane, about a first reference axis that is perpendicular to the first datum plane, a predetermined number of degrees relative to the first datum plane, and

translating the first locator plane a first predetermined distance in a predetermined direction that is perpendicular thereto;

and

the position of each film cooling hole relative to the second datum plane is determined by:

rotating a second locator plane, about a second reference axis that is perpendicular to the second datum plane, a predetermined number of degrees relative to the second datum plane, and

translating the second locator plane a second predetermined distance in a predetermined direction that is perpendicular thereto.

15. The method of Claim 14, wherein the position of each film cooling hole on the airfoil is at a location where the first and second locator planes intersect airfoil outer surface after each has been translated the first and second predetermined distances, respectively.

16. A gas turbine engine, comprising:

a compressor having an inlet and an outlet and operable to supply compressed air;

a combustor coupled to receive at least a portion of the compressed air from the compressor outlet and operable to supply combusted air; and

a turbine having a plurality of turbine blades coupled to and extending radially therefrom, the turbine coupled to receive the combusted air from the combustor and at least a portion of the compressed air from the compressor, each of the turbine blades including:

an airfoil having at least an outer surface, a bottom edge, and a top edge,

a plurality of internal cooling channels formed in the airfoil, and

a plurality of film cooling holes extending through the airfoil and in fluid communication with one of the internal cooling channels, the plurality of film cooling holes arranged into at least two adjacent rows, each row disposed on at least a portion of a line that extends between the airfoil top and bottom edges, and each film cooling hole having a centerline extending therethrough,

wherein:

(i) the centerline of each film cooling hole forms a compound angle with respect to a tangent of the airfoil outer surface, and

(ii) a distance between the centerlines of each film cooling hole is at least a predetermined minimum distance.

17. The gas turbine engine of Claim 16, wherein each film cooling hole in each row is offset from each of the film cooling holes in the adjacent row.

18. The gas turbine engine of Claim 16, wherein the compound angle of each film cooling hole centerline comprises at least a first angle formed with respect to a first predetermined datum structure and a second angle formed with respect to a second predetermined datum structure.

19. The gas turbine engine of Claim 18, wherein:
each film cooling hole has an inlet port and an outlet port; and
the outlet port of each film cooling hole is located a first predetermined distance from the first datum structure and a second predetermined distance from the second datum structure.

20. The gas turbine engine of Claim 18, wherein the first and second predetermined datum structures are first and second datum planes, respectively.

21. The gas turbine engine of Claim 20, wherein the first and second datum planes are disposed perpendicular to one another.

22. The gas turbine engine of Claim 16, further comprising:
a mounting section coupled to the upstream sidewall bottom edge and the downstream sidewall bottom edge, the mounting section adapted to couple to a turbine wheel and including one or more coolant flowpaths extending therethrough and in fluid communication with one or more of the internal coolant channels.

23. The gas turbine engine of Claim 16, wherein the centerline of each film cooling hole forms an angle with respect to a tangent to the airfoil outer surface that is between about 15-degrees and about 30-degrees

24. The gas turbine engine of Claim 23, wherein the angle is less than about 20-degrees.

25. The gas turbine engine of Claim 16, wherein the predetermined minimum distance is between about two and about four times a hole diameter.